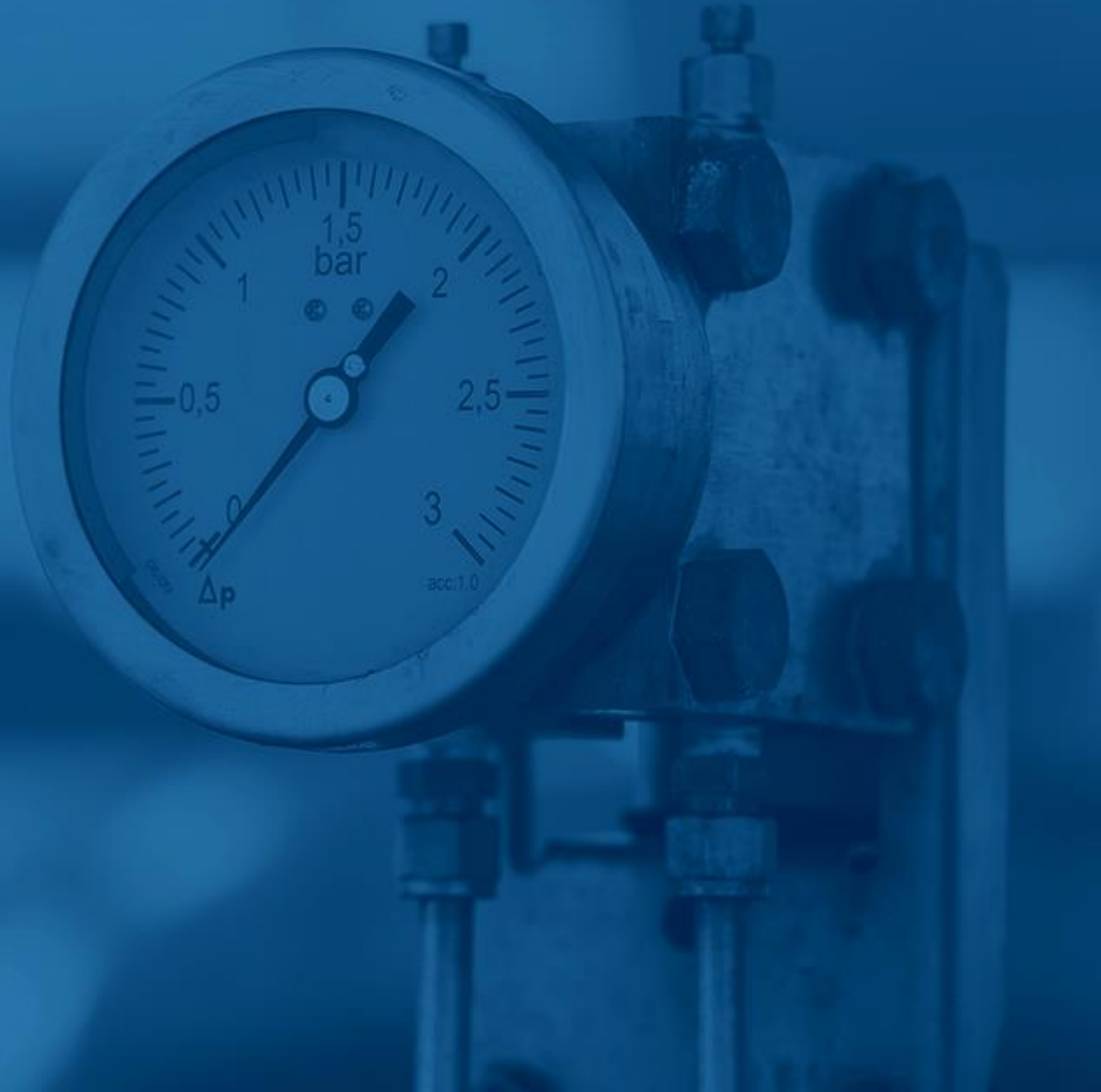
Qnect23
EC Forum

FLOWCAL by Quorum Software

Hydrocarbon Measurement Software

Jason Rigg, Solution Architect Director



Biography

Jason Rigg

Quorum Software
Solution Architect Director - Measurement

Background - 16 years in the oil & gas industry

Studied Geology, with a focus in Land Use Management

13 years in oil & gas measurement prior to joining Quorum - DCP Midstream, Black Hills, Marathon Petroleum

Outside of work

My family & I live on a small ranch in Colorado

How do we use Energy Components

- $330,000,000 NASA project ($515 million USD in 2021) to study the climate of Mars
- 669 million km (416 million mi) journey to Mars
- Program was approved in 1995 with satellite launch in 1999 (4 years of development)
- Primary objectives:
  - Determine the distribution of water on Mars
  - Monitor the daily weather and atmospheric conditions
  - Record changes on the Martian surface due to wind and other atmospheric effects
  - Determine temperature profiles of the atmosphere
  - Monitor the water vapor and dust content of the atmosphere
  - Look for evidence of past climate change

$$C_{TL} = \exp\{-\alpha_T(t-T)[1+0.8\alpha_T(t-T+\delta_T)]\}$$
$$= \exp\{-\alpha_T\Delta t[1+0.8\alpha_T(\Delta t+\delta_T)]\}$$

$$IV = \sum_{i=1}^{i=n} Q_{fi}\Delta t_i$$ is expressed as $$\sum_{i=1}^{i=n}\frac{mf_i}{k\text{-}factor_i}\sum_{j=1}^{j=z} Counts$$ or $$\sum_{i=1}^{i=n} mf_i \sum_{j=1}^{j=z}\frac{Counts}{k\text{-}factor}$$ or $$\frac{1}{k\text{-}factor}\sum_{i=1}^{i=n} mf_i\sum_{j=1}^{j=z} Counts$$

$$V = IMV\sum_{i=1}^{i=n}(DV_i\Delta t_i)$$

$$V = NC_d(FT)E_vY_1d^2\sqrt{\frac{Z_s}{Z_{f_1}}}\sum_{i=1}^{n}\left(\sqrt{\frac{h_{w_i}P_{f_1}}{G_rT_f}}\Delta t\right)$$

$$\varphi_{ethanol} = \frac{V_{60,\,ethanol}}{V_{60,\,ethanol}+V_{60,\,BOB}}$$

$$C_{PL} = \frac{1}{1-F_P(P-P_e)}.$$

$$IV = \sum_{i=1}^{i=n}\left(\sqrt{h_{w_i}P_{f_i}}\Delta t_i\right)$$

$$IMV = \left(\frac{P_f}{P_b}\right)\left(\frac{T_b}{T_f}\right)\left(\frac{Z_b}{Z_f}\right)$$

The term $\sum_{i=1}^{i=n} Q_{fi}\Delta t_i$ is called the Integral Value (IV), such that $V = IMV \times IV$.

$$\alpha_{60} = \frac{K_0+K_1\rho^* + K_2\rho^{*2}}{\rho^{*2}} = \frac{K_0}{\rho^{*2}}+\frac{K_1}{\rho^*}+K_2$$

$$IV = \sum_{i=1}^{n}\left(\sqrt{\frac{h_{w_i}P_{f_1}}{G_rT_f}}\Delta t\right)$$

For other integral value equations:

$$IV = \sum_{i=1}^{i=n}\left(\sqrt{\frac{h_{w,i}P_{f,i}}{T_{f,i}}}\Delta t_i\right) \quad DP_{IV} = \frac{\bar{T}_f}{\bar{P}_f}\left(\frac{IV}{t_f}\right)^2$$ where $\bar{T}_f$ = Flow Time Linear Average of Temperature, t_f = Flow Time

Flow Weighted Differential Pres $$F_P = \exp\left\{A+Bt+\frac{C+Dt}{\rho^{*2}}\right\}$$

$$Q_i = IMV \times DV_i$$

$$Q_v = 7709.61\,C_d(FT)E_vY_1d^2\sqrt{\frac{P_{f_1}Z_sh_w}{G_rZ_{f_1}T}}$$

$= \sum(\Delta t_i)$ for intervals when $\sqrt{h_{w_i}P_{f_i}}$ is greater than 0.

$$\sum_{i=1}\sqrt{SG_{f,i}T_{f,i}} \quad DP_{IV} = \frac{\overline{SG}_f\bar{T}_f}{\bar{P}_f}\left(\frac{IV}{t_f}\right)^2$$ where $\overline{SG}_f$ = Flow Time Linear Average of Temperature

$$z = \frac{QCP}{\Delta t}$$

$$\% \text{ Volume Difference} = \left(\sqrt{\frac{DP_{Linear}}{DP_{IV}}}-\right.$$

$$IV = \sum_{i=1}^{i=n}\left(\sqrt{h_{w_i}P_{f_i}}\Delta t_i\right)$$

$$\overline{IV} = \frac{IV}{ft} \quad \text{or} \quad IV = \overline{IV}\times ft$$

$$IV = \sum_{i=1}^{i=n}\left(\sqrt{h_{w,i}P_{f,i}}\Delta t_i\right) \quad DP_{IV} = \frac{1}{\bar{P}_f}\left(\frac{IV}{t_f}\right)^2$$ where $\bar{\rho}_f$ = Flow Time Linear Average of Density

$$\rho_{60,\,BGE,\,i} = \frac{\left(1-\frac{V_{\%ethanol_i}}{100}*(1+V_{\varepsilon,i})\right)*\rho_{60,\,BOB,\,i}+\left(\frac{V_{\%ethanol,i}}{100}*(1+V_{\varepsilon,i})\right)*\rho_{60,\,ethanol}}{1+V_{\varepsilon,i}}$$

Flow Weighted Differential Pressure ≈ $$\left(\frac{\sum_{i=1}^{i=n}(h_{w_i}\sqrt{h_{w_i}})}{n}\right)^{2/3}$$ or $$IV = \sum_{i=1}^{i=z} Q_{fi}\Delta t_i$$

$$IMV = NC_d(FT)E_vY_1d^2\sqrt{\frac{Z_s}{Z_{f_1}}}$$

$$\rho_{60,\,BGE,\,1} = \frac{\left(1-\frac{49.059}{100}*(1+0.001373)\right)*781.0+\left(\frac{49.059}{100}*(1+0.001373)\right)*788.0}{}$$

$$C_{TL} = \exp\{-\alpha_T(t-T)[1+0.8\alpha_T(t-T+\delta_T)]\}$$
$$= \exp\{-\alpha_T\Delta t[1+0.8\alpha_T(\Delta t+\delta_T)]\}$$

$$C_{PL} = \frac{1}{1-F_P(P-P_e)}.$$

Flow Weighted Differential Pressure ≈ $$\left(\frac{\sum_{i=1}^{i=n}(h_{w_i})^{3/2}}{n}\right)$$

$$V = \sum^{n}(Q_i\Delta t_i)$$

$$IV = \sum_{i=1}^{i=n} Q_{fi}\Delta t_i$$ is expressed as $$\sum_{i=1}^{i=n} mf_iQ_{mi}\Delta t_i$$ or $$\frac{1}{k\text{-}factor}\sum_{i=1}^{i=n} mf_iQ_{mi}\Delta t_i$$

$$Q = \int_{t_0}^{t_1} q(t)dt \equiv \lim_{n\to\infty}\frac{1}{n}\sum_{i=0}^{n} q_i\Delta t$$

$$DP_Y = \left[1+3.345\times\left(\frac{\sqrt{DP_{Linear}}}{\sqrt{DP_{IV}}}-1\right)\right]\times DP_L$$

$$Q_i = Q_f\left(\frac{P_f}{P_b}\right)\left(\frac{T_b}{T_f}\right)\left(\frac{Z_b}{Z_f}\right)$$

$$IV = \sum_{i=1}^{i=n} Q_{fi}\Delta t_i$$ is expressed as $$\sum_{i=1}^{i=n}\frac{mf_i}{k\text{-}factor_i}\sum_{j=1}^{j=z} Counts$$ or $$\sum_{i=1}^{i=n} mf_i\sum_{j=1}^{j=z}\frac{Counts}{k\text{-}factor}$$ or $$\frac{1}{k\text{-}factor}\sum_{i=1}^{i=n} mf_i\sum_{j=1}^{j=z} Counts$$

$$V_{\%ethanol} = \frac{V_{60,\,ethanol}}{V_{60,\,BGE}}\times 100 = \frac{V_{60,\,ethanol}}{(V_{60,\,ethanol}+V_{60,\,BOB})(1+V_\varepsilon)}\times 100$$

15 °C Base Temperature

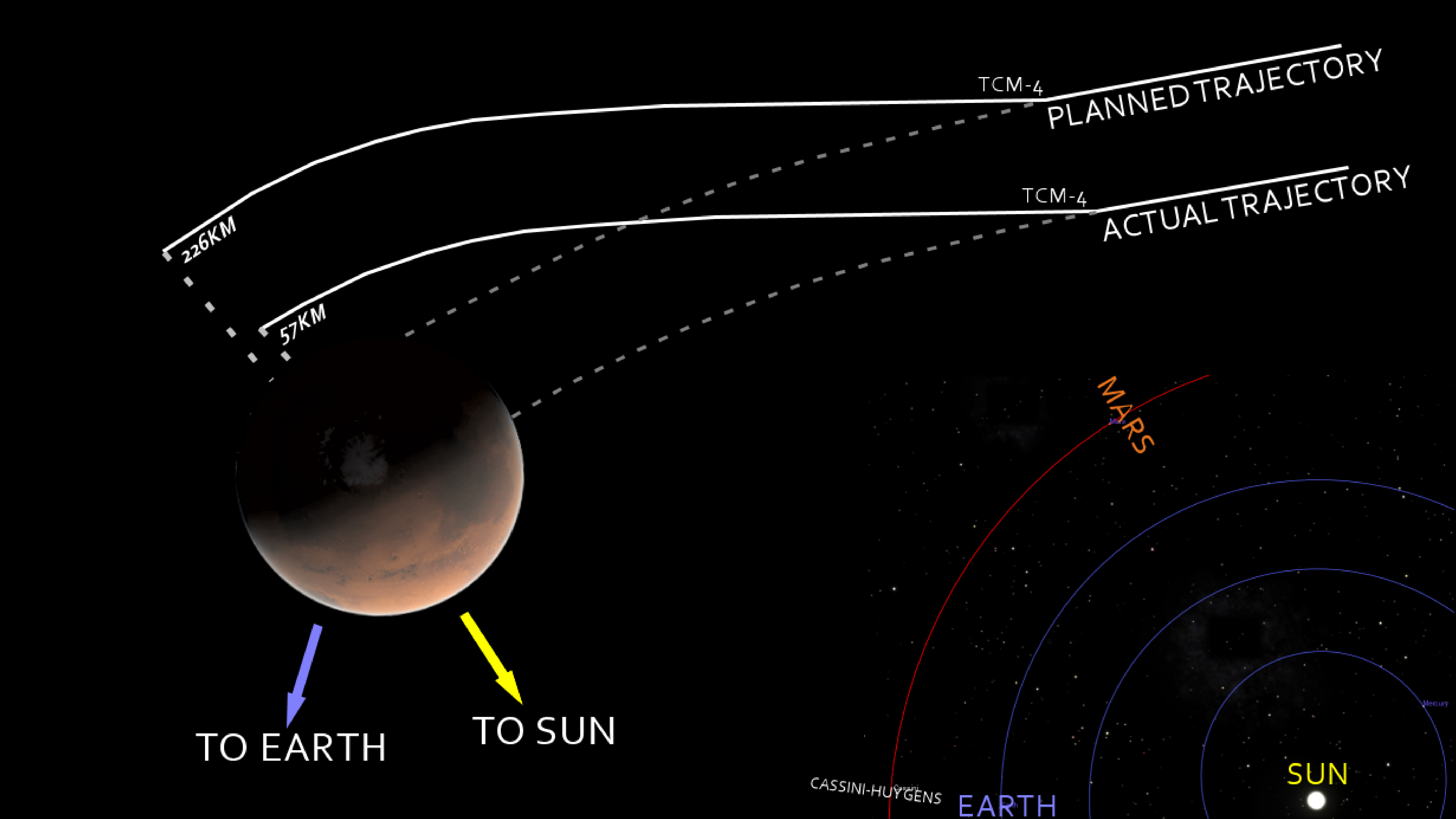
$$V_{15\,°C} = V_{57F,\,30\,psig}\times\frac{C_{TPL\,57,30\,to\,60\,°F}}{C_{TPL\,15\,°C\,to\,60\,°F}} = 99.926m^3\times\frac{1.0021125}{1.0006388} = 100.073m^3$$

$$\rho_{15\,°C} = \rho_{60}\times C_{TPL\,15\,°C\,to\,60\,°F} = 783.368\frac{kg}{m^3}\times 1.0006388 = 779.358\frac{kg}{m^3}$$

20 °C Base Temperature

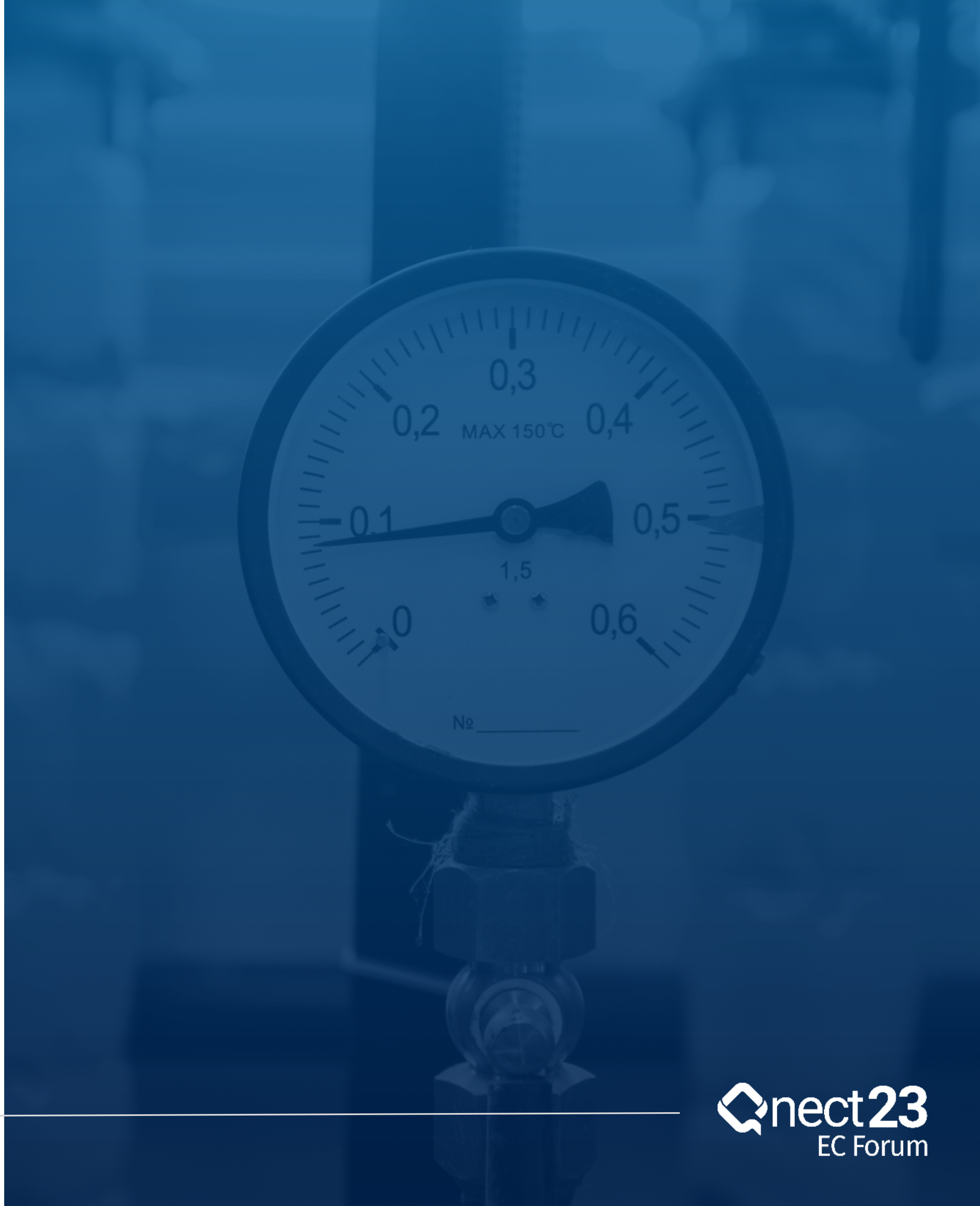
$$V_{20\,°C} = V_{57F,\,30\,psig}\times\frac{C_{TPL\,57,30\,to\,60\,°F}}{C_{TPL\,20\,°C\,to\,60\,°F}} = 99.926\times\frac{1.0021125}{0.994881} = 100.652m^3$$

$$\overline{IV} = \frac{IV}{ft} \quad \text{or} \quad IV = \overline{IV}\times ft$$


TCM-4
PLANNED TRAJECTORY
TCM-4
ACTUAL TRAJECTORY
226KM
57KM
MARS
TO EARTH
TO SUN
CASSINI-HUYGENS
EARTH
SUN

Topics

- Hydrocarbon measurement overview & challenges
- The problem statement that FLOWCAL set out to solve
- General data flow
- Types of measurement supported within FLOWCAL



Challenges with Oil & Gas Measurement







$$C_{TL} = \exp\{-\alpha_T(t-T)[1+0.8\alpha_T(t-T+\delta_T)]\}$$
$$= \exp\{-\alpha_T\Delta t[1+0.8\alpha_T(\Delta t+\delta_T)]\}$$

$IV = \sum_{i=1}^{i=n} Q_{fi}\Delta t_i$ is expressed as $\sum_{i=1}^{i=n}\frac{mf_i}{k\text{-}factor_i}\sum_{j=1}^{j=z} Counts$ or $\sum_{i=1}^{i=n} mf_i \sum_{j=1}^{j=z}\frac{Counts}{k\text{-}factor}$ or $\frac{1}{k\text{-}factor}\sum_{i=1}^{i=n} mf_i \sum_{j=1}^{j=z} Counts$

$$V = IMV\sum_{i=1}^{i=n}(DV_i\Delta t_i)$$

$$V = NC_d(FT)E_vY_1d^2\sqrt{\frac{Z_s}{Z_{f_1}}}\sum_{i=1}^{n}\left(\sqrt{\frac{h_{w_i}P_{f_1}}{G_rT_f}}\Delta t\right)$$

$$\varphi_{ethanol} = \frac{V_{60,\,ethanol}}{V_{60,\,ethanol}+V_{60,\,BOB}}$$

$$C_{PL} = \frac{1}{1-F_P(P-P_e)}.$$

$$IV = \sum_{i=1}^{i=n}\left(\sqrt{h_{w_i}P_{f_i}}\Delta t_i\right)$$

$$IMV = \left(\frac{P_f}{P_b}\right)\left(\frac{T_b}{T_f}\right)\left(\frac{Z_b}{Z_f}\right)$$

The term $\sum_{i=1}^{i=n} Q_{fi}\Delta t_i$ is called the Integral Value (IV), such that $V = IMV \times IV$.

$$\alpha_{60} = \frac{K_0+K_1\rho^*+K_2\rho^{*2}}{\rho^{*2}} = \frac{K_0}{\rho^{*2}}+\frac{K_1}{\rho^*}+K_2$$

$$IV = \sum_{i=1}^{n}\left(\sqrt{\frac{h_{w_i}P_{f_1}}{G_rT_f}}\Delta t\right)$$

For other integral value equations:

$IV = \sum_{i=1}^{i=n}\left(\sqrt{\frac{h_{w,i}P_{f,i}}{T_{f,i}}}\Delta t_i\right)$ $DP_{IV} = \frac{\overline{T}_f}{\overline{P}_f}\left(\frac{IV}{t_f}\right)^2$ where $\overline{T}_f$ = Flow Time Linear Average of Temperature, t_f = Flow Time

Flow Weighted Differential Pres $F_p = \exp\left\{A+Bt+\frac{C+Dt}{\rho^{*2}}\right\}$

$$Q_i = IMV \times DV_i$$

$$Q_v = 7709.61\,C_d(FT)E_vY_1d^2\sqrt{\frac{P_{f_1}Z_sh_w}{G_rZ_{f_1}T}}$$

$= \sum(\Delta t_i)$ for intervals when $\sqrt{h_wP_{f_i}}$ is greater than 0.

$\sum_{i=1}\left(\sqrt{SG_{f,i}T_{f,i}}\right)$ $DP_{IV} = \frac{\overline{SG}_f\overline{T}_f}{\overline{P}_f}\left(\frac{IV}{t_f}\right)^2$ where $\overline{SG}_f$ = Flow Time Linear Average of Temperature

$$z = \frac{QCP}{\Delta t}$$

% Volume Difference $= \left(\sqrt{\frac{DP_{Linear}}{DP_{IV}}} -\right.$

$$IV = \sum_{i=1}^{i=n}\left(\sqrt{h_wP_f}\Delta t_i\right)$$

$\overline{IV} = \frac{IV}{ft}$ or $IV = \overline{IV}\times ft$

$IV = \sum_{i=1}^{i=n}\left(\sqrt{h_{w,i}P_{f,i}}\Delta t_i\right)$ $DP_{IV} = \frac{1}{\overline{P}_f}\left(\frac{IV}{t_f}\right)^2$ where $\overline{\rho}_f$ = Flow Time Linear Average of Density

$$\rho_{60,\,BGE,\,i} = \frac{\left(1-\frac{V_{\%ethanol_i}}{100}*(1+V_{\varepsilon,i})\right)*\rho_{60,\,BOB,\,i}+\left(\frac{V_{\%ethanol,i}}{100}*(1+V_{\varepsilon,i})\right)*\rho_{60,\,ethanol}}{1+V_{\varepsilon,i}}$$

$$IMV = NC_d(FT)E_vY_1d^2\sqrt{\frac{Z_s}{Z_{f_1}}}$$

Flow Weighted Differential Pressure ≈ $\left(\frac{\sum_{i=1}^{i=n}(h_{w_i}\sqrt{h_{w_i}})}{n}\right)^{2/3}$ or $IV = \sum_{i=1}^{i=z} Q_{fi}\Delta t_i$

$$\rho_{60,\,BGE,\,1} = \frac{\left(1-\frac{49.059}{100}*(1+0.001373)\right)*781.0+\left(\frac{49.059}{100}*(1+0.001373)\right)*788.0}{}$$

$$C_{TL} = \exp\{-\alpha_T(t-T)[1+0.8\alpha_T(t-T+\delta_T)]\}$$
$$= \exp\{-\alpha_T\Delta t[1+0.8\alpha_T(\Delta t+\delta_T)]\}$$

Flow Weighted Differential Pressure ≈ $\left(\frac{\sum_{i=1}^{i=n}(h_{w_i})^{3/2}}{n}\right)$

$$V = \sum(Q_i\Delta t_i)$$

$IV = \sum_{i=1}^{i=n} Q_{fi}\Delta t_i$ is expressed as $\sum_{i=1}^{i=n} mf_iQ_{mi}\Delta t_i$ or $\frac{1}{k\text{-}factor}\sum_{i=1}^{i=n} mf_iQ_{mi}\Delta t_i$

$$C_{PL} = \frac{1}{1-F_P(P-P_e)}.$$

$$Q = \int_{t_0}^{t_1} q(t)dt \equiv \lim_{n\to\infty}\frac{1}{n}\sum_{i=0}^{n} q_i\Delta t$$

$$DP_Y = \left[1+3.345\times\left(\frac{\sqrt{DP_{Linear}}}{\sqrt{DP_{IV}}}-1\right)\right]\times DP_L$$

$$Q_i = Q_f\left(\frac{P_f}{P_b}\right)\left(\frac{T_b}{T_f}\right)\left(\frac{Z_b}{Z_f}\right)$$

$IV = \sum_{i=1}^{i=n} Q_{fi}\Delta t_i$ is expressed as $\sum_{i=1}^{i=n}\frac{mf_i}{k\text{-}factor_i}\sum_{j=1}^{j=z} Counts$ or $\sum_{i=1}^{i=n} mf_i \sum_{j=1}^{j=z}\frac{Counts}{k\text{-}factor}$ or $\frac{1}{k\text{-}factor}\sum_{i=1}^{i=n} mf_i \sum_{j=1}^{j=z} Counts$

$$V_{\%ethanol} = \frac{V_{60,\,ethanol}}{V_{60,\,BGE}}\times 100 = \frac{V_{60,\,ethanol}}{(V_{60,\,ethanol}+V_{60,\,BOB})(1+V_\varepsilon)}\times 100$$

15 °C Base Temperature

$$V_{15\,^\circ C} = V_{57F,\,30\,psig}\times\frac{C_{TPL\,57,30\,to\,60\,^\circ F}}{C_{TPL\,15\,^\circ C\,to\,60\,^\circ F}} = 99.926m^3\times\frac{1.0021125}{1.0006388} = 100.073m^3$$

$$\rho_{15\,^\circ C} = \rho_{60}\times C_{TPL\,15\,^\circ C\,to\,60\,^\circ F} = 783.368\frac{kg}{m^3}\times 1.0006388 = 779.358\frac{kg}{m^3}$$

20 °C Base Temperature

$$V_{20\,^\circ C} = V_{57F,\,30\,psig}\times\frac{C_{TPL\,57,30\,to\,60\,^\circ F}}{C_{TPL\,20\,^\circ C\,to\,60\,^\circ F}} = 99.926\times\frac{1.0021125}{0.994881} = 100.652m^3$$

$\overline{IV} = \frac{IV}{ft}$ or $IV = \overline{IV}\times ft$

Qnect23 EC Forum

The Problem Statement

Problem statement variables:

- Hydrocarbon measurement is complex
- Datasets are massive
- Field measurements are performed in suboptimal conditions due to weather & atmosphere
- Instrumentation requires manual configuration and human error is prevalent
- An inherent gap between the field & office (physical gap & knowledge gap) presents risk & exposure in measurement data
- Electronics failures are a common issue

Given this set of challenges, how can we ensure that measurement is accurate prior to be used in financial & logistical transactions?

Why does that matter?

Measurement drives financial transactions

- A realistic 0.3% error on custody transfer liquid measurement has an impact of $150k per oil tanker
- Incorrect application of temperature & density to the applicable correction tables can cause 3%-5% errors regularly, representing millions of dollars in revenue
- Inaccurate application of Meter Factor will have significant impact on volumetric calculations
- Using a saturated vs dry heating value causes a 1.7% error in calculation. 105,000 GJ/month = $6,700 usd error/month
- Electronics failures regularly cause calculations errors within the flow computer causing financial errors due to incorrect measurements

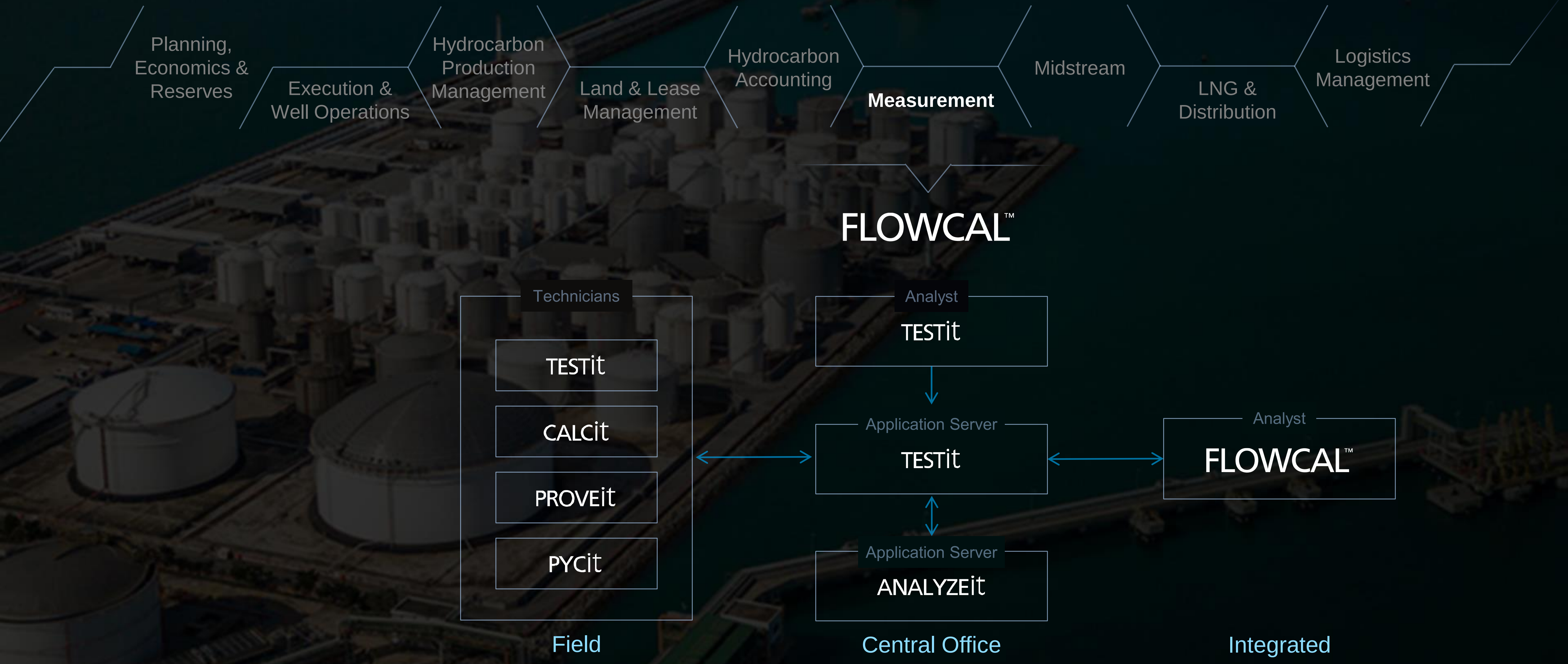
Measurement is playing a key role in emissions tracking and energy transition

As Carbon Capture and Sequestration continues to grow, the industry needs processes to accurately quantify

Various governments have specific regulation & reporting requirements for measurement data

FLOWCAL

Measurement Software to Consolidate, Validate, Correct, Balance, and Report Meter Data for Gas and Liquids



General Data Flow

Primary function

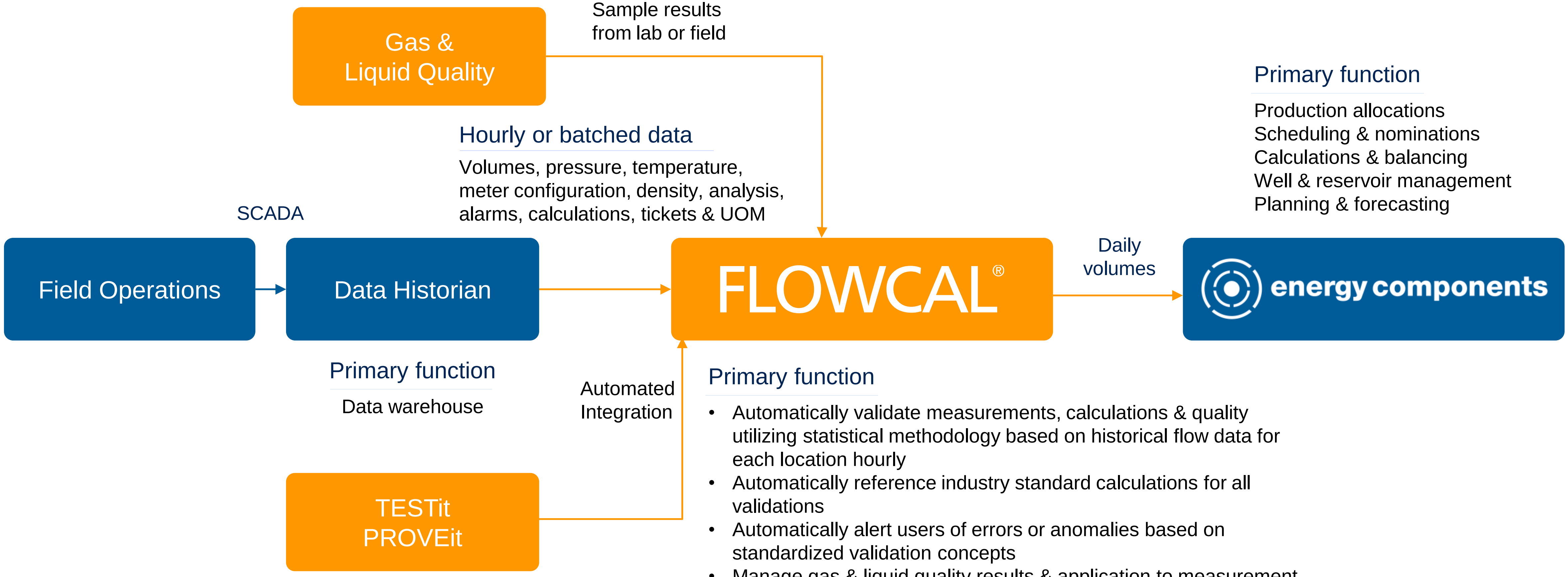
Data warehouse

Primary function

Production allocations
Scheduling & nominations
Calculations & balancing
Well & reservoir management
Planning & forecasting

General Data Flow

General Data Flow



Primary function (energy components)

Production allocations
Scheduling & nominations
Calculations & balancing
Well & reservoir management
Planning & forecasting

Primary function (Data Historian)

Data warehouse

Primary function (FLOWCAL)

- Automatically validate measurements, calculations & quality utilizing statistical methodology based on historical flow data for each location hourly
- Automatically reference industry standard calculations for all validations
- Automatically alert users of errors or anomalies based on standardized validation concepts
- Manage gas & liquid quality results & application to measurement
- Perform edits & recalculations per standard calculations
- Automated adjustments for test reports & QA/QC for configuration
- Apply quality to measurement per
- Convert from liquids to gas for balancing in single phase
- Manage tanks utilizing strapping tables & product
- Mass, energy & volume balancing from a technical perspective

Primary function (TESTit PROVEit)

Meter proving Transmitter verification/calibration
Meter configuration reports

Types of Measurement Managed in FLOWCAL

Product calculations and specifications supported in FLOWCAL:

- All grades of crude oil
- Natural gas
- Condensate
- Natural gas liquids
- Energy transition & Net Zero
  - CO_2 – in both gas & supercritical/dense phase to support CCS operations
  - Renewable natural gas (RNG)
  - Methanol, Ethanol & Biodiesel
- Refined products, lubricating oils, light hydrocarbons, aromatics, cyclohexane, Ethylene
- Gas & liquid quality
- Water

75+ standard calculations are supported from the following organizations:

- American Petroleum Institute (API)
  - Quorum Software/FLOWCAL has partnered with the API to create & maintain the API 11.1 calculations and to be the sole distributor globally
- International Organization for Standardization (ISO)
- American Gas Association (AGA)
- Gas Processors Association (GPA)
- ASTM International

Summary

The results of hydrocarbon measurement drive trillions of dollars of financial transactions globally, every year

The measurements performed are inherently risky and prone to error due to suboptimal conditions, human error and electronic failure

Across the entire energy value chain, operators (producers, midstream operators, pipeline & distribution) need automated tools to ensure measurement is accurate prior to financial transactions

As nations strive to reduce their carbon footprint and meet their Net Zero initiatives, track emissions and capture carbon, measurement requirements will continue to grow

Mars Climate Orbiter